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Halite clogging in a deep geothermal well – Geochemical and isotopic characterisation of salt origin

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ABSTRACT

The sandstone formation of the Middle Buntsandstein (Lower Triassic) in the geothermal well Groß Buchholz Gt1, Hanover, Northern Germany, was hydraulically stimulated to generate a heat exchanger surface, using 20000 m^3 of fresh water. After six months of enclosure the recovered water was oversaturated with respect to halite at surface conditions. Due to cooling induced precipitation a salt plug formed between 655 and 1350 m depth in the tubing. While the Na/Br and the Cl/Br ratio of the recovered water reflect the signature of a relic evaporative solution the recovered water contains tritium, indicating a significant proportion of fresh water. Leaching experiments of the reservoir rocks point towards presence of traces of soluble salt minerals in the formation. Therefore we assume that the salinity cannot be attributed solely to halite dissolution nor to the production of a pure formation brine. The recovered water is a result of a combination of both salt dissolution by injected fresh water and of mixing with a formation brine which has undergone water–rock interaction. The calculated fresh water proportion in the recovered water is around 40%. The presence of salt mineral traces in pores of a target formation is a potential threat for the operation of geothermal wells, as cooling-induced salt scaling jeopardizes their performance.

1. Introduction

Geothermal energy is a very promising source of renewable energy which is being investigated in many parts of the world. Deep sedimentary basins such as the Northern German Basin (NGB) provide potential target horizons.

The NGB consists of mostly horizontally bedded sediments of Mesozoic and Cenozoic age. Sediments of suitable temperature for geothermal exploitation often have low to negligible porosity and consequently low permeability. To develop and test possibilities to generate geothermal energy from these sediments of low permeability, the GeneSys project (generated geothermal energy systems) was initiated in 2003 (Kehrer et al., 2005).

The project intends to provide thermal energy (2 MW_{th}) for a building complex in Hanover (Fig. 1). For this purpose, the geothermal well Groß Buchholz Gt1, approximately 4 km deep, was drilled in 2009. The well was prospected to reach the sandstones of the Middle Buntsandstein (Lower Triassic) (Fig. 2). The innovative aspect of the project was the "single-well" approach for producing from the Triassic and injecting the thermal water in the more shallow Cretaceous sandstone through the annulus for storage (Kehrer et al., 2005).

Because of the very tight (<1 mDarcy) sediments of the Middle Buntsandstein it was necessary to generate an artificial fracture as an underground heat exchanger. The technique was tested in a research project at the deep well Horstberg Z1 (Fig. 1) which is located approximately 80 km north of Hanover. The stratigraphic profile of Horstberg Z1 is similar to the one of Groß Buchholz Gt1 and its production horizon is the same (Tischner et al., 2010). Results from analysis of the formation brine were available from several production tests.

With this experience and the results of a pretest in Gt1 an artificial fracture at Groß Buchholz Gt1 was generated in 2011, injecting 20,000 m^3 of fresh water into the well. After six months of enclosure the water was recovered in order to deduce hydraulic and hydrochemical data of the fracture and the reservoir conditions. During the tests, the injected and produced water was sampled in intervals. The comparison of the results allowed characterising the geochemical properties of the reservoir. Immediately after exchanging the water volume of the tubing, the salinity of the produced water increased abruptly. The water became oversaturated with respect to halite at production conditions, so that several parts of the above-surface equipment clogged and failed immediately. Intense cooling occurred in the production tubing, so that a salt plug developed in 655 m depth, which clogged the well. The production test had to be stopped. One year after the recovery test the salt plug was removed by injecting fresh water

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Fig. 1. Map of Germany with regions with geothermal potential (shaded, after Schulz et al., 2007). Geothermal wells Groß Buchholz Gt1 and Horstberg Z1 are marked with open circles.

with a capillary coil unit (Multiline). With interruptions the salt plug went down to 1350 m.

Prior to the injection of fresh water it was not possible to sample the originally present formation brine due to the very low permeability. The porosity of the formation rocks ranges between 1 and 2 vol.% (pers. comm. J. Orilski, Leibniz-Institute for Applied Geophysics (LIAG), 2012). In spite of this, the rocks are most likely watersaturated with no free gas phase.

Fig. 2 shows the geology of the well Groß Buchholz Gt1, as well as the well completion and an estimate of the dimensions of the artificial fracture. The real fracture dimensions are still unknown due to insufficient hydraulic data. The estimate shown is based on rock mechanical model pre-calculations (Tischner et al., 2013). According to these, the fracture has a plane of around 0.6 km^2 with a maximum length of 2000 m, maximum height of 400 m and maximum width of 3 cm at the injection point. It is noteworthy that strata containing rock salt (footwall: Zechstein formation, headwall: Röt formation, Upper Buntsandstein) are present in the proximity of the fracture.

Because no capacities to store the produced water above ground were available, it was reinjected into a more shallow storage horizon. Based on previous investigations, discussed by Schäfer et al. (2012), a sandstone formation in the lower Cretaceous (Wealden sandstone) at 1200 m depth was selected.

In this paper we compare the compositional changes between injected and recovered water, both for the pretest and the fractest. In addition, we compare the results with a test at Horstberg Z1 in the same formation. The aim is to infer the geochemical in situ

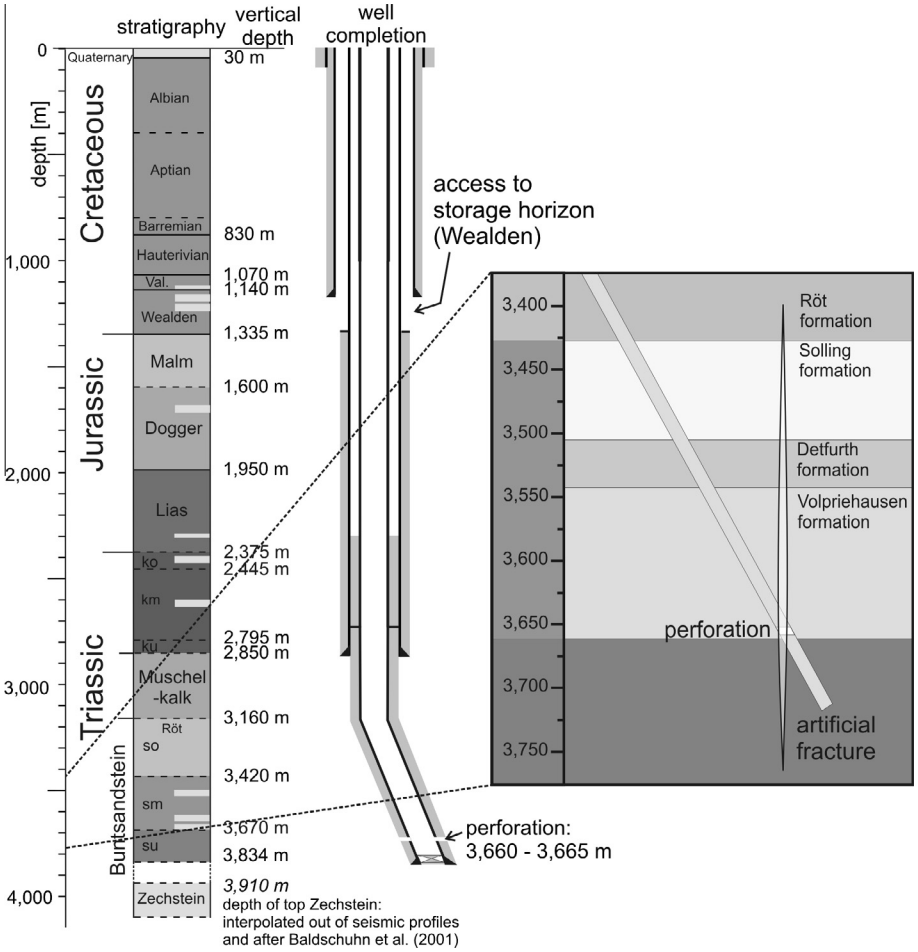

Fig. 2. Stratigraphic profile and sketch of well completion of geothermal well Groß Buchholz Gt1. The target horizon lies in approximately 3750–3400 m and the storage formation in approximately 1200 m. Right: zoom into the target horizon, the likely fracture dimensions are displayed as side face. The fracture plane proceeds perpendicular to the drawing area. The depth of the Zechstein top was interpolated from seismic profiles and after data from Baldschuhn et al. (2001).